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MARITIME PATROL AIRCRAFT (MPA) CONCEPT FORMULATION. ALLISON PD3--ETC(U)  
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This study developed data on Detroit Diesel Allison (DDA) common core derivative engines for use in Maritime Patrol Aircraft (MPA) concept formulation studies. The study included the screening of potential DDA turboprop/turboshift engines and the preparation of technical and planning information on three of the most promising engine candidates plus an all new engine. Screening of DDA derivative candidates was performed utilizing an analytical MPA model using synthesized mission profiles to rank the candidates in terms		

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of fuel consumption, weight, cost and complexity. The three turboprop engines selected for further study were as follows: a derivative of the unity size T701-AD-700 shaft power engine with rematched turbine (PD 370-37), an advanced T701 turboprop derivative with 25:1 overall pressure ratio and a scaled ATEGG demonstrated compressor (PD 370-40), an advanced T701 turboprop derivative with 17.7:1 overall pressure ratio and a scaled ATEGG demonstrated compressor (PD 370-41). Data is also presented on a new advanced turboprop engine with 30:1 overall pressure ratio which incorporates compressor, combustor, turbine, and cooling technology now under development and demonstration at DDA. The documentation consists of six separate reports prepared in the following manner. One report summarizes the engine screening analysis and describes the approach to, and the conclusions of the study. A separate report for each of the three derivative engines and for the new turboprop present estimates of performance, weight, and dimensional data. The engineering budgetary estimates of the development, acquisition, and service costs for each of the four engines are presented in a separate report.

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## REVISIONS

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A	4	Gearbox and total weight
A	6	Gearbox, interconnecting struts and shaft, and total weight
A	9	Scaling factors
A	10	Additional matrix points at 0 and 25,000 feet
A	13	Additional performance
A	18	Additional performance
A	23	Additional performance
A	28	Additional performance



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## I. INTRODUCTION

This report presents estimates of performance, weight, and dimensional data for the PD 370-40 turboprop engine. The PD 370-40 represents an advanced T701 turboprop derivative engine with 25:1 overall pressure ratio. It incorporates a scaled ATEGG demonstrated compressor with basic shaft, bearing and turbine arrangements from the new T701 turboshaft engine. The engine is in the 12,000 to 13,000 SHP class, but scaling data is included to provide for studies down to 6000 SHP. The data is submitted for use in preliminary design type studies in the evaluation of turboprop systems.

The basic T701 engine is a free turbine turboshaft engine that was developed through safety demonstration testing, for the U.S. Army's HLH program. The model 570, a commercial industrial version of the T701, has undergone additional development testing, and is now in production.

The reduction gearbox for speed reduction to the prop-fan is a new simplified design, compared to the DDA T56 series of gearboxes. The new design is based upon a study into the reliability and maintenance cost history of past turboprop systems, and follows the recommendations of that study for a gearbox with high reliability, easy maintainability, and low maintenance costs.



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## II. ENGINE DESCRIPTION

The Model PD 370-40 is an axial flow engine, having a single spool core and a free power turbine connected by shafting, and supporting structure to an offset reduction gear assembly. The general arrangement and external features of the engine are shown in Figure II-1, with principle physical characteristics listed in Table II-I. Output speed of the engine is constant at 9545 RPM. The reduction gearbox shown in Figure II-1 has an overall gear ratio of 7.52:1, providing a propfan speed of 1270 rpm at 9545 engine rpm. Parametric weight data is shown in Section III so that other propfan rotational speeds, and gear ratios can be analyzed. An aircraft accessory drive pad is provided on the back of the gearbox to drive an aircraft mounted accessory drive box. Power available at this pad is 500 HP at 8000 rpm. The primary engine mounts are on the gearbox with a hang mount at the rear of the engine. Engine accessories are driven by a bevel drive from the high pressure spool. The control system is integral with the prop-fan and is digital electronic. The oil system is integral to the engine and also supplies the prop-fan and reduction gearbox, but is separately filtered and monitored to isolate fault detection in each of these major modules. Engine torque is measured hydraulically from the gear thrust of the power train idler gears in the reduction gearbox.

The gearbox is shown offset, based upon DDA's experience with large turboprop engines. It is offset-up to be consistent with current studies showing a preference to under-the-wing engine mounting. It can also be supplied in the offset-down position.

Performance ratings, sea level static, are listed in Table II-II.

For preliminary design studies, the PD 370-40 engine configuration can be scaled to other power ratings. Scaling information is included for dimensions, weight, and performance.



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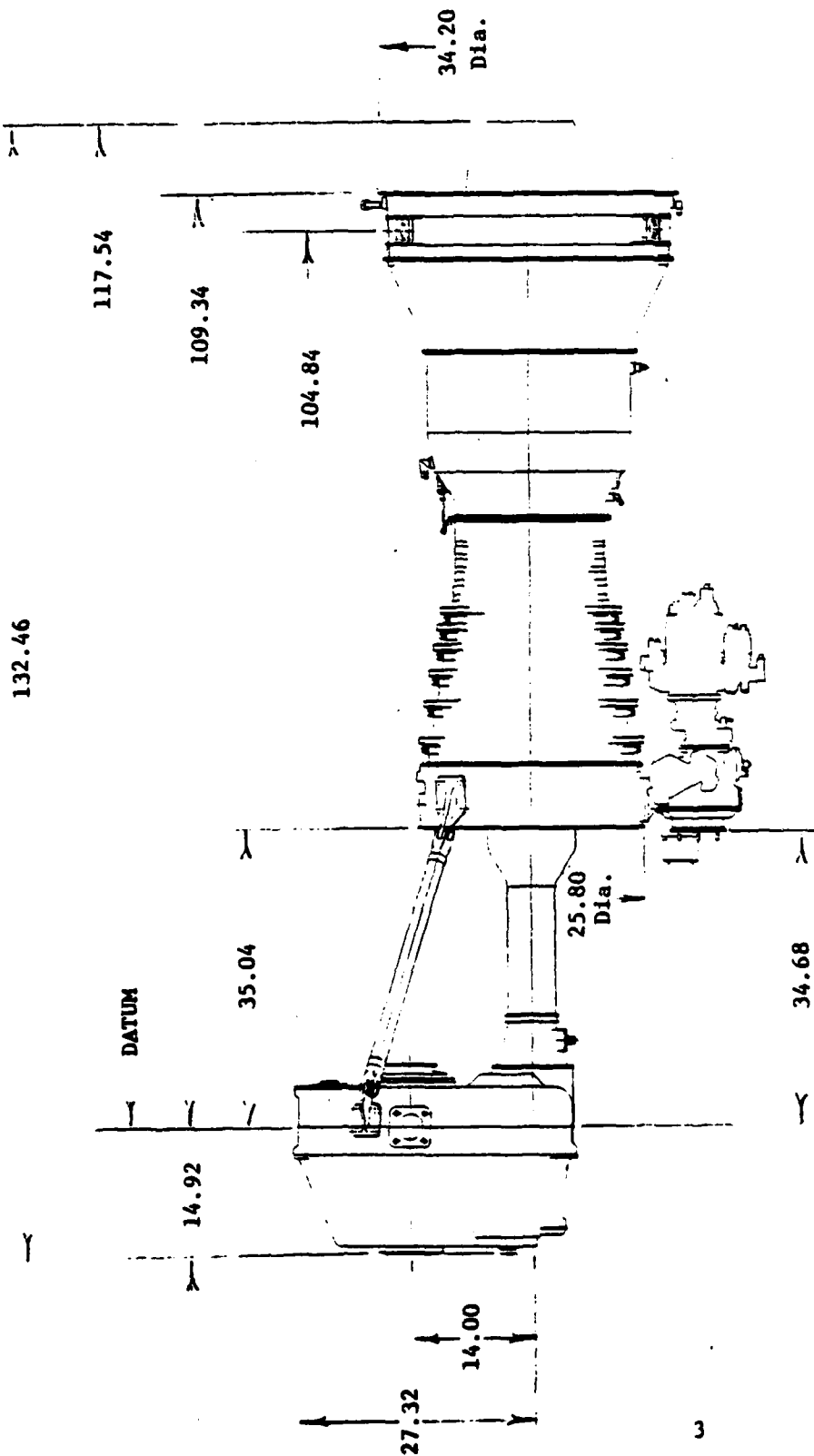


Figure II-1. PD370-40 General Arrangement.





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TABLE II-I

PD 370-40 PHYSICAL CHARACTERISTICS

(Includes Gearbox)

Length (in)	132.46
Max. Engine Diameter (in)	34.20
Max. Gearbox Offset, upward ( in)	27.32
Dry Weight, lbs	
Engine	1566
Gearbox, including interconnecting struts and shaft	848
Total	2414

For scaling dimensions the following formulae may be used for SHP's down to 6000, and for other reduction gear ratios than 7.52:1.

Engine

$$\text{Axial dimensions} = \text{Base dim.} \times \left( \frac{\text{SHP}}{13,386} \right)^{0.4}$$

$$\text{Diameters} = \text{Base dia.} \times \left( \frac{\text{SHP}}{13,386} \right)^{0.5}$$

Reduction Gearbox

$$\text{Dimensions} = \text{Base dim.} \times \left( \frac{\text{SHP}}{13,386} \right)^{0.5} \times \left( \frac{\text{GR}}{7.52} \right)^{0.33}$$

Shaft length remains unchanged.



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TABLE II-II

PD370-40 PERFORMANCE SUMMARY

Sea Level, 0 kts

	<u>Standard Day</u>			<u>Hot Day, 89.8°F</u>		
	SHP	SFC	F <sub>N</sub>	SHP	SFC	F <sub>N</sub>
Take-Off	13,386	0.373	1,540	13,351	0.379	1,491
Max. Continuous	9,770	0.393	1,105	7,934	0.418	871



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### III. WEIGHTS

The weight of the basic 13,386 SHP engine, gearbox, and the interconnecting struts and shaft are given in Table III-I. The gearbox weight is based upon a gear ratio of 7.52:1 which provides a propfan speed of 1270 rpm.

TABLE III-I

PD 370-40 WEIGHTS

	<u>Dry</u>	<u>Wet</u> *	<u>Installed</u>
Basic Engine, lbs	1566	1589	1589
Gearbox, lbs	800	849	849
Interconnecting Struts and Shaft, lbs	48	48	48
	—	—	—
Total, lbs	2414	2486	2486

\* Includes total amount of oil required for engine and gearbox operation.

For scaling weights to engine sizes down to 6000 SHP, and for other reduction gear ratios, the following formulae may be used:

$$\text{Engine weight} = 1566 \times \left( \frac{\text{HP}}{13,386} \right)^{1.01}$$

$$\text{Gearbox weight} = 800 \times \left( \frac{\text{HP}}{13,386} \right)^{1.5} \times \left( \frac{\text{GR}}{7.52} \right)^{0.4}$$

Interconnecting strut and shaft weight = 6.0% of dry gearbox weight



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#### IV. STEADY STATE PERFORMANCE

Steady state performance data is tabulated in this section for all points shown in Figure IV-1. Basic engine data is shown for the following assumptions:

- o Uninstalled engine
- o ICAO standard atmosphere except for takeoff which in addition includes an ambient temperature of 89.8°F at standard atmosphere
- o 100% inlet recovery
- o Zero accessory horsepower extraction
- o Zero customer bleed extraction
- o Zero losses due to reduction gear
- o Fuel heating value - 18,400 Btu/lb
- o Estimated average engine performance - No SHP or fuel flow guarantee factors

Sensitivity data is provided for each point so that bleed and duct losses may be estimated as required.

#### Nomenclature

Nomenclature used in the tabulation of performance is as follows:

MACH	Mach number
SHP	Shaft horsepower
SFC	Specific fuel consumption, lbs/hr/hp
WF	Engine fuel flow, lbs/hr
FN	Net jet thrust, lbs (jet gross thrust - ram drag)
ESHP	Equivalent shaft horsepower (energy in jet stream converted ideally to horsepower and added to SHP)
WCIN	Total inlet corrected airflow, $W\sqrt{\theta_1}/\delta_1$

where:  $\theta_1$  = Engine inlet total temp, °R  
 $\frac{518.688}{}$



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$$\delta_1 = \frac{\text{Engine inlet total pressure, psi}}{14.696}$$

TNOZ	Jet nozzle total temperature, °R
PNOZ	Jet nozzle total pressure, psi
RC	Compressor pressure ratio
BOT	Burner outlet temperature, °R
NO	Point number

#### Sensitivity Data

##### Bleed:

$$\text{SHP, with bleed} = \text{SHP, no bleed} - (\text{DEL SHP})(\% \text{ bleed})$$

$$\text{WF, with bleed} = \text{WF, no bleed} - (\text{DEL WF})(\% \text{ bleed})$$

$$\text{FN, with bleed} = \text{FN, no bleed} - (\text{DEL FN})(\% \text{ bleed})$$

##### Inlet Recovery:

$$\eta_R = \text{Total pressure actual/Total pressure ideal}$$

$$\text{SHP, with recovery} = \text{SHP, ideal recovery} - (\text{DEL SHP})(1 - \eta_R)(100)$$

$$\text{WF, with recovery} = \text{WF, ideal recovery} (\eta_R)$$

$$\text{FN, with recovery} = \text{FN, ideal recovery} - (\text{DEL FN})(1 - \eta_R)(100)$$

##### Jet Nozzle Duct Loss:

To estimate thrust loss due to additional duct loss prior to the jet nozzle, use the following equation:

$$\text{FN, with loss} = \text{FN, without loss} - \text{FN, without loss} (K) \left( \frac{\Delta P}{P} \right)$$

where,

o K is obtained for each point from sensitivity data

$$o \frac{\Delta P}{P} = \frac{\text{PTOT, no loss} - \text{PTOT, total loss}}{\text{PTOT, no loss}}$$



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**Reduction Gear Loss:**

Reduction gear is 99 percent efficient.

**Accessory Drive Losses:**

Accessory drive power extraction is directly from the accessory drive pad on the reduction gearbox. Reduce SHP to prop-fan by amount of accessory power extraction at each point.

**Scale Effect on SHP and SFC:**

The engine performance is scaleable for purposes of studying other engine sizes. However, component performance will vary, dependent upon the amount of scale. A correction to scale factor for SHP and SFC was formulated for component performance changes and the effects on SHP, SFC, and FN are as follows:

$$\text{Scaled SHP} = \text{Unscaled SHP} \times \left(1 - \frac{A}{100}\right) \times \text{Scale Factor}$$

$$\text{Scaled FN} = \text{Unscaled FN} \times \text{Scale Factor}$$

$$\text{Scaled SFC} = \text{Unscaled SFC} \times \left(1 + \frac{B}{100}\right)$$

where:

$$\text{Scale Factor} = \frac{\text{Desired Rating}}{\text{Unity Rating}} \left( \text{limited from 1.2 to 0.6} \right)$$

A = Sizing effect on SHP

$$= 27.29 \times \text{Scale factor} - 11.90 \times (\text{Scale factor})^2 - 15.39$$

B = Sizing effect on SFC

$$= 7.15 \times (\text{Scale factor})^2 - 17.70 \times \text{Scale factor} + 10.54$$

**Nozzle Throat Area**

The effective nozzle throat area is constant for all conditions at 491.4 in<sup>2</sup>.



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Standard and Hot Day; Takeoff and Maximum Continuous

Altitude (Ft $\times 10^{-3}$ )	MACH Number			
	0	.1	.2	.3
0	X	X	X	X

Standard Day; Maximum Climb, Maximum Continuous and Part Power to Idle

Altitude (Ft $\times 10^{-3}$ )	MACH Number							
	.2	.3	.4	.5	.6	.7	.75	.8
0	X	X	X	X	X	X	X	X
5	X	X	X	X	X			
10	X	X	X	X	X	X	X	X
15		X	X	X	X	X	X	X
20			X	X	X	X	X	X
25			X	X	X	X	X	X
30				X	X	X	X	X
35				X	X	X	X	X
40				X	X	X	X	X
45				X	X	X	X	X

Figure IV-1. Matrix of flight conditions for performance data

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**ZERO POWER EXTRACTION**

POWER	NACH	SHP	SFC	WF	FN	ESHP	WCIN	TNOZ	PNOZ	RC	NO
TO	00	10	0000000000	00	0000000000	00	00	00	00	00	0001
N.C.	00	10	0000000000	00	0000000000	00	00	00	00	00	0002
N.C.	00	10	0000000000	00	0000000000	00	00	00	00	00	0003
N.C.	00	10	0000000000	00	0000000000	00	00	00	00	00	0004
N.C.	00	10	0000000000	00	0000000000	00	00	00	00	00	0005
N.C.	00	10	0000000000	00	0000000000	00	00	00	00	00	0006
N.C.	00	10	0000000000	00	0000000000	00	00	00	00	00	0007
N.C.	00	10	0000000000	00	0000000000	00	00	00	00	00	0008

**T AMBIENT = 89.8° F**

0 FEET ALTITUDE



DETROIT DIESEL ALLISON DIVISION

EDR 9775

PD370-40 TURBOPROP

SENSITIVITY DATA FOR BLEED, INLET RECOVERY, AND EXHAUST DUCT LOSS

0 FEET ALTITUDE

POWER	MACH	DEL-SUP	INLET DEL	DEL FR	DEL SHP	PER DEL	DEL BLEED	DEL FR	K	NO
TO	0.0	202.0	29.0	0.2	308.0	0.0	0.0	1.0	4.0	0001
N.C.	0.1	167.0	27.0	0.3	271.0	0.0	0.0	1.0	4.0	0002
N.C.	0.2	167.0	27.0	0.3	271.0	0.0	0.0	1.0	4.0	0003
N.C.	0.3	167.0	27.0	0.3	271.0	0.0	0.0	1.0	4.0	0004
N.C.	0.4	167.0	27.0	0.3	271.0	0.0	0.0	1.0	4.0	0005
N.C.	0.5	167.0	27.0	0.3	271.0	0.0	0.0	1.0	4.0	0006
N.C.	0.6	167.0	27.0	0.3	271.0	0.0	0.0	1.0	4.0	0007
N.C.	0.7	167.0	27.0	0.3	271.0	0.0	0.0	1.0	4.0	0008

T AMBIENT = 89.8°F

0 FEET ALTITUDE

POWER	MACH	DEL-SUP	INLET DEL	DEL FR	DEL SHP	PER DEL	DEL BLEED	DEL FR	K	NO
TO	0.0	202.0	29.0	0.2	308.0	0.0	0.0	1.0	4.0	0009
N.C.	0.1	167.0	27.0	0.3	271.0	0.0	0.0	1.0	4.0	0010
N.C.	0.2	167.0	27.0	0.3	271.0	0.0	0.0	1.0	4.0	0011
N.C.	0.3	167.0	27.0	0.3	271.0	0.0	0.0	1.0	4.0	0012
N.C.	0.4	167.0	27.0	0.3	271.0	0.0	0.0	1.0	4.0	0013
N.C.	0.5	167.0	27.0	0.3	271.0	0.0	0.0	1.0	4.0	0014
N.C.	0.6	167.0	27.0	0.3	271.0	0.0	0.0	1.0	4.0	0015
N.C.	0.7	167.0	27.0	0.3	271.0	0.0	0.0	1.0	4.0	0016



# МІЛІОНІВНИЙ ЕКСТРАКЦІЙНИЙ

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RU 370-40 / UKUUP KUP

NOTHING BUT THE TRUTH

**SID DAY**

5000 FLEET ALTIMETER

המחלקה לבריאות הציבור

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GENERAL MOTORS CORPORATION  
LEAK PUMPER EXTRACTUM

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 PUJ70-40 JUKBUPKUP  
 100 PLKCEK RECOVERY  
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GENERAL MILK'S CORPORATION  
ZENO POWER EXTRACTION

LUK 9775  
PDJ10-40 JMBWPHUP  
100 PERCENT RELUVENY  
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DETAILED DIESEL ALLISON DIVISION  
ZAKARYAH

[illegible]

DETROIT DIESEL ALLISON DIVISION  
ZERO BLEED

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GENERAL MOTORS CORPORATION  
ZERO POWER EXTRACTION

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PU370-40 LUMUPKUP  
100 PERCENT RECOVERY  
STU DAY

WE FRUIT VEGEL ALLISON DIVISION

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**GENERAL MUTUALS CORPORATION**

## ZERO POWER EXTRACTION

9775 JK 216

RU 370-40 IUKBPKJP

100 PERCENT KLUVER

**THIS WAY**

4,000 FEET ALTITUDE

DEIRK J. DIESEL ALLISON DIVISION

ZERU BLEED

[illegible]

**EDR 9775**

PD370-40 TURBOPROP

**GENERAL MOTORS CORPORATION**

### SENSITIVITY DATA FOR BLEED, INLET RECOVERY, AND EXHAUST DUCT LOSS

### 0 FEET ALTITUDE

**POWER**

**CLIMB M.C.**

**CLIMB M.C.**

**CLIMB M.C.**

**CLIMB M.C.**

**CLIMB M.C.**

**MACH**

**DEP SPD INTL REF**

**DEP SPD INTL REF**

**DEP-DEI-MF-LEED DEL FR**

**K**

**N**

**NO**

GENERAL MOTORS CORPORATION

LUR 9/75

DETROIT DIESEL ALLISON DIVISION

P0370-40 TURBOCHARGER

SENSITIVITY DATA FOR BLEED, INLET RECOVERY, AND EXHAUST DUCT LOSS

5000 FEET ALTITUDE

PLWLR	MACH	PER-SHP-INLET-DEL-FN	DEL-SHP	PER-DEL-WHEEL-DEL-FN	K	NO
CLIMB M.C.	0.00	1.17	2.20	4.50	1.00	0049
	0.01	1.16	2.19	4.51	1.00	0050
	0.02	1.15	2.18	4.52	1.00	0051
	0.03	1.14	2.17	4.53	1.00	0052
	0.04	1.13	2.16	4.54	1.00	0053
	0.05	1.12	2.15	4.55	1.00	0054
	0.06	1.11	2.14	4.56	1.00	0055
	0.07	1.10	2.13	4.57	1.00	0056
	0.08	1.09	2.12	4.58	1.00	0057
	0.09	1.08	2.11	4.59	1.00	0058
	0.10	1.07	2.10	4.60	1.00	0059
	0.11	1.06	2.09	4.61	1.00	0060
	0.12	1.05	2.08	4.62	1.00	0061
	0.13	1.04	2.07	4.63	1.00	0062
	0.14	1.03	2.06	4.64	1.00	0063
	0.15	1.02	2.05	4.65	1.00	0064
	0.16	1.01	2.04	4.66	1.00	0065
	0.17	1.00	2.03	4.67	1.00	0066
	0.18	0.99	2.02	4.68	1.00	0067
	0.19	0.98	2.01	4.69	1.00	0068
	0.20	0.97	2.00	4.70	1.00	0069
	0.21	0.96	1.99	4.71	1.00	0070
	0.22	0.95	1.98	4.72	1.00	0071
	0.23	0.94	1.97	4.73	1.00	0072
	0.24	0.93	1.96	4.74	1.00	0073
	0.25	0.92	1.95	4.75	1.00	0074
	0.26	0.91	1.94	4.76	1.00	0075
	0.27	0.90	1.93	4.77	1.00	0076
	0.28	0.89	1.92	4.78	1.00	0077
	0.29	0.88	1.91	4.79	1.00	0078
	0.30	0.87	1.90	4.80	1.00	0079
	0.31	0.86	1.89	4.81	1.00	0080
	0.32	0.85	1.88	4.82	1.00	0081
	0.33	0.84	1.87	4.83	1.00	0082
	0.34	0.83	1.86	4.84	1.00	0083
	0.35	0.82	1.85	4.85	1.00	0084
	0.36	0.81	1.84	4.86	1.00	0085
	0.37	0.80	1.83	4.87	1.00	0086
	0.38	0.79	1.82	4.88	1.00	0087
	0.39	0.78	1.81	4.89	1.00	0088
	0.40	0.77	1.80	4.90	1.00	0089
	0.41	0.76	1.79	4.91	1.00	0090
	0.42	0.75	1.78	4.92	1.00	0091
	0.43	0.74	1.77	4.93	1.00	0092
	0.44	0.73	1.76	4.94	1.00	0093
	0.45	0.72	1.75	4.95	1.00	0094
	0.46	0.71	1.74	4.96	1.00	0095
	0.47	0.70	1.73	4.97	1.00	0096
	0.48	0.69	1.72	4.98	1.00	0097
	0.49	0.68	1.71	4.99	1.00	0098
	0.50	0.67	1.70	5.00	1.00	0099

LUK 5772

PU370-40 IUKBLYKUP

**WELSH DIESEL ALLIANCE**

# SENSITIVITY DATA FOR BLEED, INLET RECOVERY, AND EXHAUST VULC LOSS

10000 FEET ALLIUM

[illegible]

**GENERAL MOTORS CORPORATION**

SENSITIVITY DATA FOR BLEED, INLET RECOVERY, AND EXHAUST DUCT LOSS  
15000 FEET ALTITUDE

PUNCH  
 LLIMU  
 M.L.  
 LLIMB  
 M.L.  
 RM.TT  
 M.L.  
 CLIMB  
 M.L.  
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 LLIMB  
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 MACH

DEVELOPMENTAL DIESEL ALLIANCE DIVISION

PU37U-4U TUKBUPKLP

### SENSITIVITY DATA FOR BLEED, INLET RECOVERY, AND EXHAUST DUCT LOSS

## 20000 FEET ALTITUDE

[illegible]





ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED

LUK 5775

PL 10-40 IUKUJPKUP

**GENERAL AUTUMS CORPORATION**

SENSITIVITY DATA FOR BLEED, INLET RECOVERY, AND EXHAUST DUCT LOSS  
30000 FEET ALTITUDE

[illegible]

UNIVERSITY MICROFILMS

5116 4715

# GENERAL MOTORS CORPORATION

PL 70-40 1 JAN 21 1948

### SENSITIVITY DATA FOR BLEED, INLET RECOVERY, AND EXHAUST DUCT LOSS

300111TV 1334 00056.

[illegible]



**GENERAL MUTUAL CORPORATION**

РМД 70-40 1 УНДЛУРКУЛР

SENSITIVITY DATA FOR BLEED, INLET RECOVERY, AND EXHAUST DUCT LOSS

## 45,000 FEET ALTITUDE

32